Floating Population Structure in Shrinking Area of Shanghai Metropolitan Area: An Urban-Rural Mobility Network Analysis

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Abstract
With the advancement of urbanization in China, urban and rural areas are experiencing different trends and structural changes in population mobility. In particular, some shrinking areas exhibit diverse and complex migration patterns. However, few studies have examined these areas from the perspective of spatial mobility networks. This paper employs an urban-rural population mobility network analysis to explore the structural characteristics and movement patterns of the floating population in the shrinking areas of the Shanghai metropolitan area. It identifies the key factors influencing population structure and provides new insights for local governments to promote regional and urban-rural integration and to formulate effective policies for managing shrinking areas.

Keywords: Population structure; Floating population; Shrinking area; Network analysis; Shanghai metropolitan area

1. Introduction

China's long-standing planning practices have been dominated by a growth-oriented development paradigm, leading to the neglect of urban shrinkage. However, with the intensification of low fertility and population aging, the country is entering a stage of overall population decline. As policies promoting regional integration and urban-rural fusion take effect, the siphoning effects of central cities have led to varying degrees and types of shrinkage across many urban agglomerations and metropolitan areas. While Chinese scholars have mainly focused on urban shrinkage in the Northeast due to long-term reliance on resource-based industries, less attention has been paid to shrinkage in economically developed regions such as the Yangtze River Delta and Pearl River Delta. Yet, research has already identified signs of shrinkage in parts of cities like Shanghai and in certain counties and small towns within cities like Taizhou, Yancheng, Nantong, Jiaxing, and Wuxi. As a result, China's traditional growth-driven urbanization model may no longer be applicable, marking the arrival of a post-growth era in urban development.

Current research on shrinking areas primarily focuses on cities, with relatively little attention given to shrinking towns. However, towns are often typical areas experiencing population loss, aging, and hollowing out during China's urbanization process, facing the dual challenges of natural population decline and out-migration. Population structure has profound implications for regional economic development and long-term competitiveness, which in turn determines whether regional shrinkage is temporary or long-term. Martinez-Fernandez (2013, p. 303-308) suggested that from the perspective of global urban networks and spatial mobility networks, shrinking cities may experience a weakening or even severing of their connections to global flows. However, empirical studies testing this hypothesis remain limited. Compared to research on urban networks, studies focusing on urban-rural network characteristics are scarce. Therefore, this study aims to explore the characteristics of shrinking areas within metropolitan regions from the perspective of spatial network linkages, emphasizing the population agglomeration capacity of towns. Unlike Western countries, China's ongoing urbanization has made population loss less pronounced in cities. Urban shrinkage in China is not only a result of internal urban factors but also of regional and spatial interactions. Thus, examining shrinking areas through the lens of factor flows provides a more effective way to assess their future development trajectories.

This study focuses on all towns within the Shanghai metropolitan area, an area characterized by frequent economic interactions and distinct network connectivity. First, traditional demographic data are used to calculate population changes in each town, providing a preliminary identification of shrinking towns. Next, massive mobile phone mobility data are utilized to construct urban-rural and rural-rural population flow networks within the metropolitan area. By analyzing population travel profiles—including flow volumes and demographic attributes

such as age and gender—this study examines the population mobility and structural characteristics of shrinking towns. It identifies key influencing factors, ultimately proposing optimization strategies. By adopting the novel perspective of population mobility networks, this study offers a new analytical framework for understanding shrinking areas in metropolitan area and provides valuable insights for promoting regional coordination, urban-rural integration, and the development of targeted policies for managing shrinking areas in China.

2. literature review

At present, the definition of shrinking areas is primarily based on population change and involves multiple dimensions such as demographics, economy, and time. However, due to differences in national development contexts and statistical standards, there is no unified measurement criterion. Moreover, the phenomenon of shrinkage in China's urbanization process has unique characteristics, and changes in population size alone may not objectively reflect regional shrinkage.

Existing studies on shrinking cities tend to focus on descriptive analysis. However, with the ongoing processes of economic globalization and regional integration, the traditional "place-based economy" rooted in comparative advantages of resource endowments is gradually being replaced by a "flow-based economy" centered on capital, technology, markets, and innovation, with flow space becoming the mainstream paradigm. In economics, some scholars have begun using total factor productivity combined with econometric methods as criteria to determine regional shrinkage or growth (Yang, 2022). Wu (2021) utilized a unique dataset on intercity investment flows in mainland China to demonstrate a significant positive correlation between network centrality of investment and population change, revealing a link between urban shrinkage and the loss of external investment. Sun (2022) proposed that urban shrinkage reflects a relative or absolute decline in a city's "regional capacity to agglomerate development factors" within regional linkages, leading to the "relocation" of population and other key development factors—a market-driven behavior, with population outflow being merely a manifestation. With the emergence of flow space theory, research on spatial networks has deepened, and advances in information technology have enabled the use of mobile signaling data and Internet app-generated big data to track various flows. These data, supported by increasingly mature algorithms, are widely applied in studies of urban agglomeration and metropolitan spatial structures, thus making it increasingly feasible to analyze shrinking areas from the perspective of element flows.

The identification of shrinking cities has primarily relied on static data analysis, lacking dynamic analysis from the perspective of network connectivity and an essential understanding based on the outflow of development factors. Overall, current methods for identifying shrinking cities are mostly population-centered, using statistical and spatial data to construct multi-dimensional indicator systems. With technological advancement, simulation-based models have also begun to emerge (Liu, 2016). While prefecture-level cities remain the main unit of measurement, studies identifying shrinkage at the district, county, and township levels are increasing.Some scholars have proposed that, from the perspective of global urban networks and spatial flow networks, shrinking cities may also exhibit a weakening or even severance of their connections to global flow spaces—particularly in terms of knowledge and information flows (Martinez-Fernandez, 2014). The inequality between cities and regions integrated into global networks and those excluded from them is intensifying. Cities connected to global networks are the "winners," while others struggle to maintain ties and survive in global economic competition. Cities bypassed by global networks may fall into what Castells termed the "black holes" of globalization—isolated from or disconnected from global growth engines. Therefore, shrinking cities can also be analyzed through their association with urban factor networks. By constructing regional factor networks based on factor flows, areas with weak or disrupted connections to other parts of the region can be identified, thereby detecting cities with shrinkage tendencies.

Research on population structure has mostly relied on static statistical analysis, with limited focus on how population structures evolve in shrinking cities. Demographic structure is often only used as an indicator for identifying shrinkage, rather than as a subject of study in itself. There is a lack of systematic investigation into how population structures change in shrinking cities and how these changes in turn affect urban population,

economic, and social development. Yet demographic shifts can profoundly influence regional economic growth. Therefore, integrating the study of mobile populations with population structure is crucial for understanding the socioeconomic impacts of population decline (Chen, 2025).

3. Methodology and data

3.1 Research area and data source

The Shanghai Metropolitan Area, located in eastern China, is a key component of the Yangtze River Delta. In 2022, the governments of Shanghai, Jiangsu Province, and Zhejiang Province jointly released the "Shanghai Metropolitan Region Spatial Coordination Plan", which aims to advance the national strategy of integrated development in the Yangtze River Delta. The planned area includes the administrative regions of nine cities: Shanghai, Wuxi, Changzhou, Suzhou, Nantong, Ningbo, Huzhou, Jiaxing, and Zhoushan—referred to as the "1+8" city cluster. The Metropolitan Area features diverse patterns of population agglomeration and, as the most functionally concentrated and economically advanced area within the Yangtze River Delta, it is characterized by a high degree of economic clustering and rapid development. With multiple interconnected centers and a strong need for close collaboration, the region plays a pivotal role in driving coordinated regional development. Therefore, integrated urban-rural development holds particular importance for the Shanghai Metropolitan Region.

This study takes the Shanghai Metropolitan Area as the research area, dividing the nine cities into 913 sub-city administrative units at the street (township) level. Based on the "Statistical Compilation Rules for Administrative Division Codes and Urban-Rural Division Codes" (index no. 410A03-1201-201708-0006) issued by the National Bureau of Statistics, each administrative unit was classified by its urban-rural attribute using the first digit of its urban-rural classification code: 1 for urban areas and 2 for rural areas. In total, 404 urban streets and 495 townships were identified.

This study primarily uses statistical data and mobile signaling data. Population statistics are derived from China's Sixth Population Census (2010) and Seventh Population Census (2020), both providing resident population data at the street and town levels. The mobile signaling data consist of weekday origin-destination (OD) travel data from October 2022. Users' movements were located using cell tower grids, and their residence and workplace locations were identified by the longest stay during nighttime and daytime, respectively. The population flow analysis in this study focuses mainly on work-related commuting based on residential origins.

3.2 Research approach and methodology

Compared with traditional studies that explore the characteristics of shrinking areas using static statistical data, this research aims to examine the features of shrinking regions within metropolitan areas from the perspective of regional spatial network linkages, focusing on the population agglomeration capacity of towns. Therefore, this study first adopts the conventional but crucial indicator of population change by calculating population growth rates to identify areas with significant population decline. Next, based on large-scale population mobility data, a population flow network is constructed for the Shanghai Metropolitan Area. This network is analyzed at two levels: urban–rural and rural–rural population flows. These levels respectively represent the connections between shrinking towns and both urban subdistricts and neighboring towns, and can reflect, to some extent and in a timely manner, the ability of shrinking towns to attract and retain population development factors. Based on the constructed networks, the structural characteristics of mobile populations in shrinking towns are statistically analyzed in both urban–rural and rural–rural networks. This analysis is of great significance to promoting urban-rural integration and coordinated development in the Shanghai Metropolitan Area.

The first step involves identifying shrinking towns. Although there is no consensus in academia on how to define shrinking areas, negative population growth remains a key criterion. Given the continued urbanization in China and its significant impact on rural populations, this study follows relevant methodologies (Wang and Xue, 2016; Cheng, Zhang and Liu, 2021) by first selecting towns with negative population growth between 2010 and 2020. Then, the average population change rate is calculated for all townships in Jiangsu Province, Zhejiang Province, and Shanghai. By computing the relative population change rates that exclude the impact of urbanization,

townships within the metropolitan area that still exhibit negative relative growth are defined as shrinking towns.

The second step focuses on analyzing the population mobility network. Using mobile signaling data, the subdistricts and towns are treated as network nodes, and the total bidirectional commuting trips between them are used as the measure of network connection strength. This enables the construction of an urban–rural and rural–rural commuting population network within the metropolitan region. Commuting flows reflect labor force mobility and indicate the degree of productive economic collaboration between regions. Based on this, statistical analyses are conducted on the gender, age, and other characteristics of the mobile population in shrinking towns.

4. Results and discussion

4.1 Distribution characteristics of shrinking towns

Based on the calculation of town-level relative population change rates after excluding the impact of urbanization, a total of 135 shrinking townships were identified in the Shanghai Metropolitan Region. In terms of quantity, Shanghai and Nantong have the highest number of shrinking townships, with 31 and 33 respectively, mainly concentrated in Chongming District (Shanghai) and Rudong County (Nantong). Suzhou, Wuxi, and Changzhou have fewer shrinking townships, each in the single digits, while Zhoushan, Ningbo, Jiaxing, and Huzhou each have around 15.

In terms of spatial distribution, the shrinking townships in the Shanghai Metropolitan Region show a combination of localized clustering and a perforated pattern, mainly concentrated in peripheral areas of the metropolitan region and the border zones between cities. Overall, although current research using cities or districts as the statistical unit does not indicate significant population decline within cities in the Shanghai Metropolitan Region, a more detailed analysis at the township level reveals varying degrees of shrinkage within cities. This better reflects the unique development characteristics of different areas. For example, towns in the Suzhou-Wuxi-Changzhou area maintain stable population levels due to a solid industrial base and balanced internal economic development. In contrast, the areas surrounding Shanghai are affected by the strong siphoning effect of the central urban core and related policies, leading to frequent population mobility in towns. (Figure 1)

Given the limitations of traditional population statistics, shrinking towns in different regions should be further categorized and analyzed. Big data sources such as population mobility data can dynamically reflect the current development status of towns.

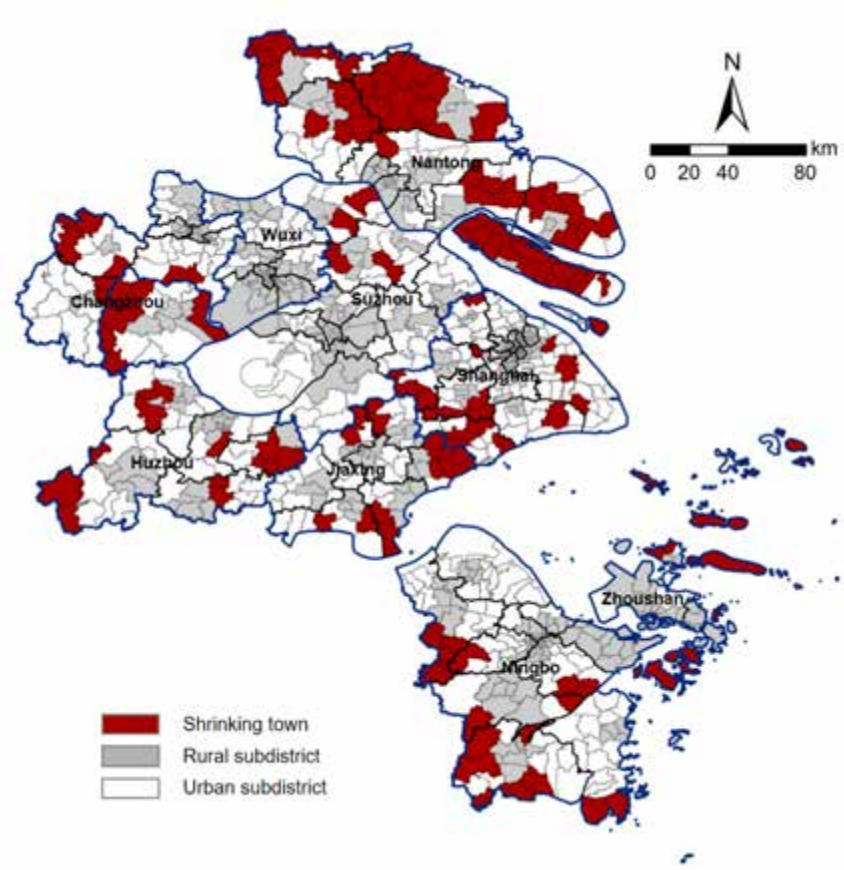

Figure 1. Location, urban-rural classification and shrinking towns layouts of Shanghai metropolitan area

4.2 Connection characteristics of shrinking towns

The travel connections of shrinking townships were filtered and visualized . In both the urban–rural and rural–rural networks, shrinking townships show stronger internal connectivity within their respective districts or counties, indicating the significant constraint imposed by administrative boundaries. However, cross-boundary connections are more prominent in the rural–rural network, suggesting that inter-township interactions are less influenced by administrative borders.

Among the 2 types of networks, shrinking townships in Shanghai, Suzhou, and Jiaxing exhibit higher overall connection volumes, while those in Ningbo, Zhoushan, and Huzhou generally show lower levels of external connectivity. This may be due to topographical constraints such as the Siming Mountains and Tianmu Mountains. In the urban–rural network, shrinking townships are not only closely linked to urban subdistricts within their counties but also maintain functional connections with central urban areas. In the rural–rural network, the connections between shrinking townships and other rural areas appear more evenly distributed.**(Figure 2)**

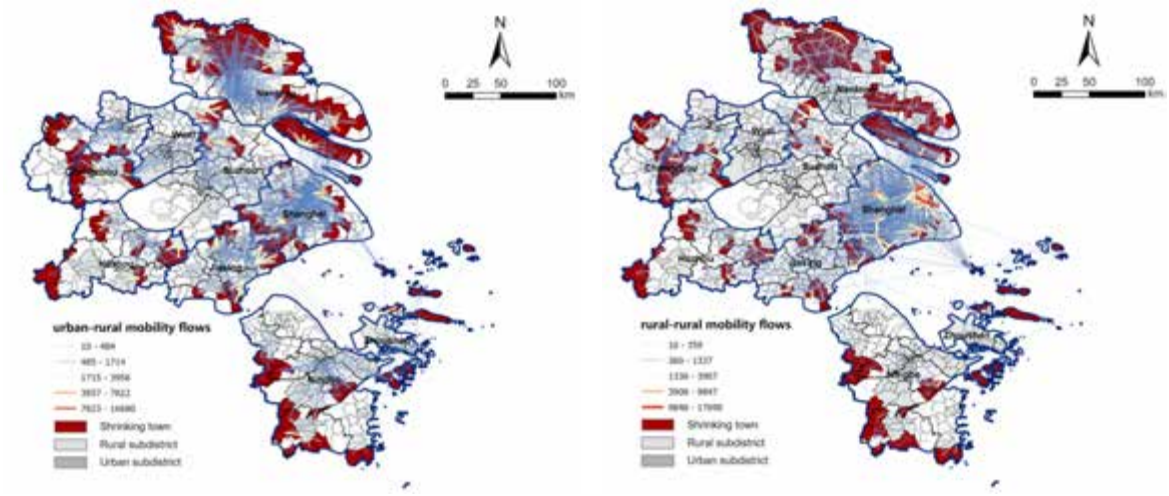

Figure 2. Characteristics of urban - rural population flow network in shrinking towns of Shanghai metropolitan area

4.3 Structural characteristics of the floating population in shrinking towns

The structural characteristics of the floating population in shrinking towns are analyzed from five key aspects: gender, age, education level, income, and consumption level. By comparing the characteristics and differences of the floating population between rural–rural and urban–rural flows, this study conducts a comparative analysis of the overall development trends and internal disparities within the shrinking towns.

4.3.1 Gender characteristics

In both rural–rural and urban–rural population mobility networks, the proportion of males is higher than that of females, which is closely related to the development characteristics of townships. As the main labor force, men are typically the primary source of household income in these areas. In the rural–rural mobility network, the gender imbalance is more pronounced, with a male-to-female ratio of approximately 1.4:1. This indicates that in township labor distribution, men are mainly engaged in labor-intensive industries such as construction and logistics, while women are more likely to migrate through marriage or work in the service sector.

In the urban–rural mobility network, the gender ratio is more balanced at 1.1:1. This suggests that urban–rural labor flows are more likely to involve couples working together or seeking nearby employment opportunities, reflecting a trend of "family-based migration." **(Figure 3)**

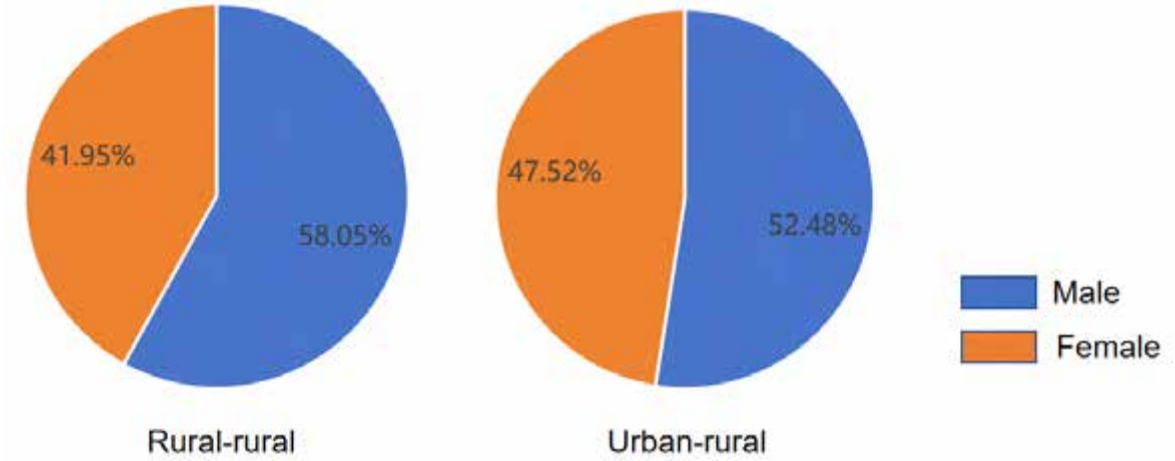

Figure 3. Gender characteristics of floating population in Shanghai metropolitan area

4.3.2 Age characteristics

Among the mobile labor population in shrinking townships, young and middle-aged individuals aged 16–35 remain the main force. In the urban–rural mobility network, this age group accounts for a higher proportion—up to 70.19%—reflecting the strong demand for young labor in urban labor-intensive industries and physically demanding jobs, which attracts more people to engage with urban areas.

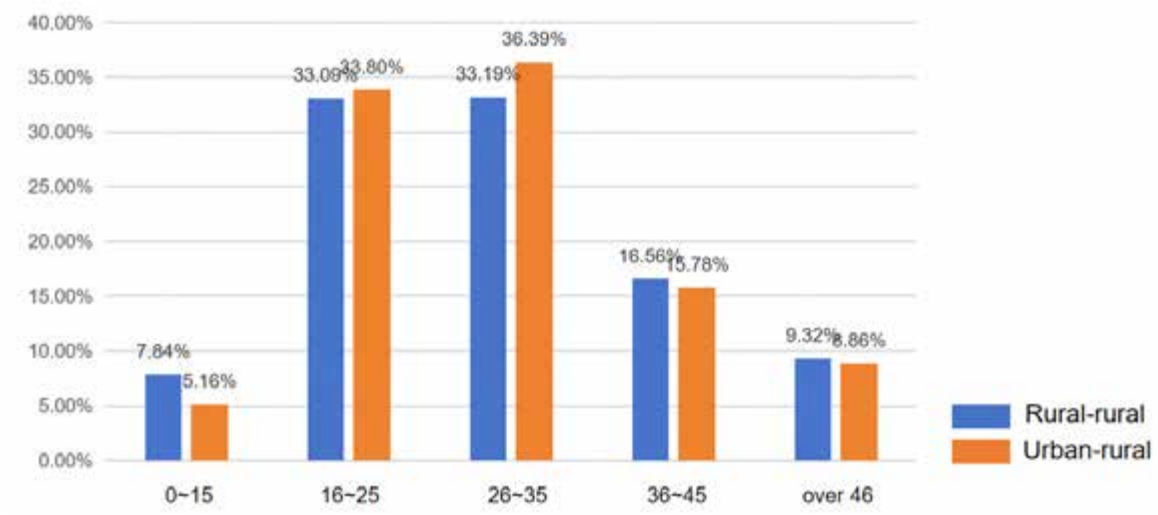

Figure 4. Age characteristics of floating population in Shanghai metropolitan area

In contrast, the proportions of elderly and youth within the mobile population are relatively low, showing a polarized distribution. In the rural–rural mobility network, the proportions of youth and middle-aged or elderly individuals are slightly higher, indicating that these groups tend to move over shorter distances between townships **(Figure 4)**.

4.3.3 Educational attainment

The education level of the mobile labor population in shrinking townships is categorized into three types: high (associate degree and above), middle (high school or vocational school), and low (junior high school and below). The educational attainment of this population shows a polarized pattern, with a predominance of individuals with higher education levels. This differs from internal rural–rural mobility and suggests that those leaving the townships tend to be more highly educated, which is often associated with skill advantages and higher income levels.

Among the urban-rural mobile population, the proportion of individuals with higher education is significantly greater. This indicates that, in addition to some medium- and low-educated laborers, there is also a group of well-educated and skilled professionals. This trend aligns with the industrial structure of the Shanghai metropolitan area, where the secondary and tertiary sectors dominate, and agriculture holds less competitive advantage-resulting in a labor force with relatively higher education levels.

In contrast, the rural-rural mobile population has a higher proportion of individuals with lower education levels. This group is likely engaged in agricultural work, basic manufacturing, or service-sector jobs that require minimal skills.**(Figure 5)**

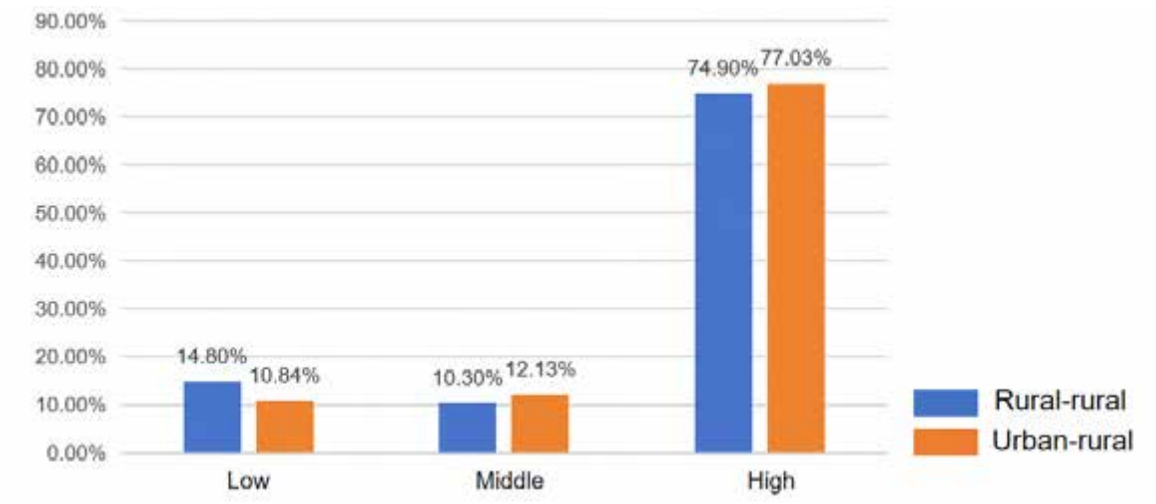

Figure 5. Educational attainment characteristics of floating population in Shanghai metropolitan area

4.3.4 Income and consumption level

In terms of income and consumption levels, both types of mobile populations-urban-rural and rural-rural-are primarily characterized by low income and low consumption, which is closely related to the overall level of development in townships. For township residents, incomes tend to be unstable and grow slowly. Consumption is generally low, focused on basic needs such as food and clothing, with relatively limited spending on housing, education, healthcare, and other areas.

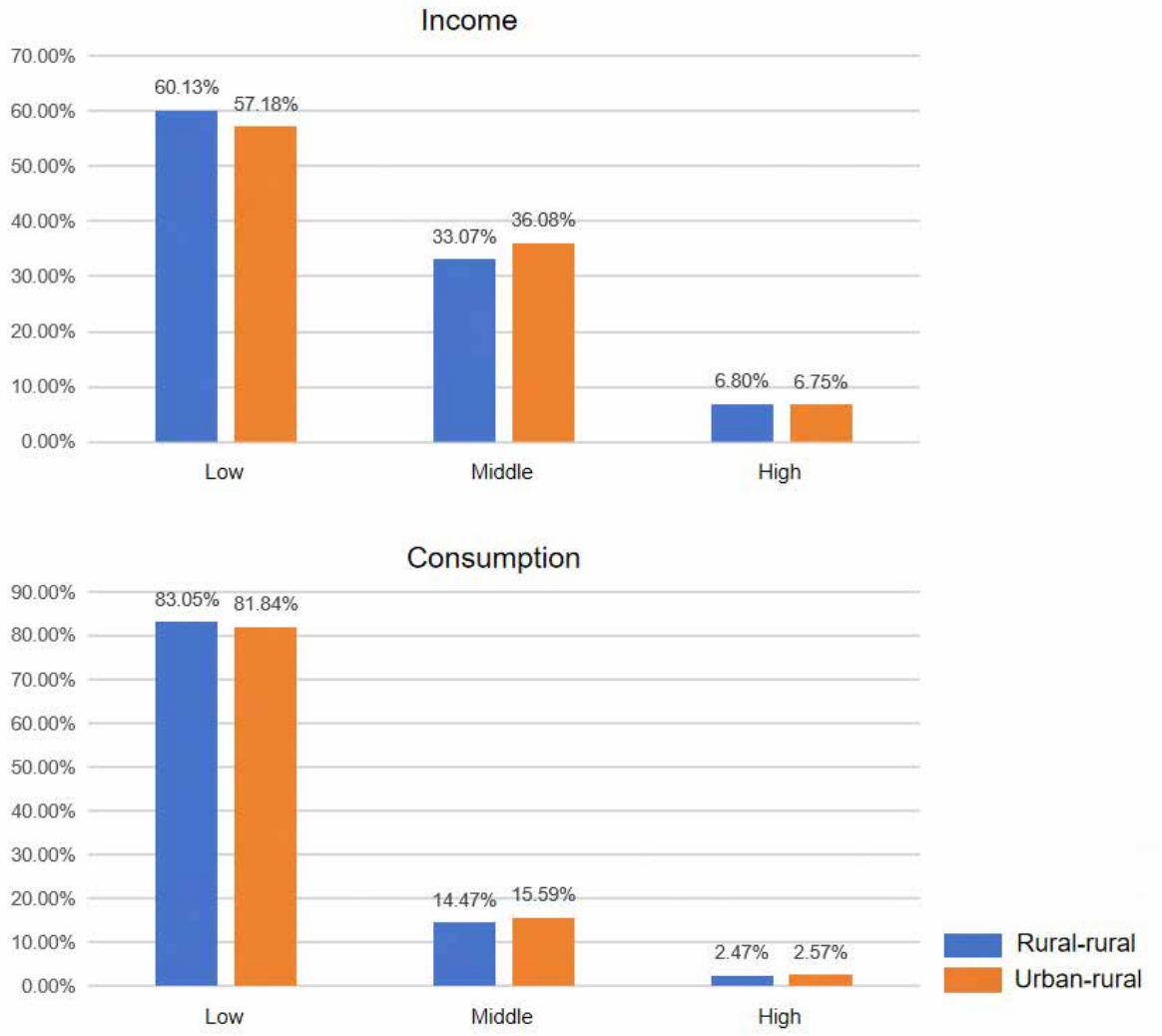

Figure6. Income and consumption characteristics of floating population in Shanghai metropolitan area

However, among the urban-rural mobile population, the proportion of individuals with medium income and consumption levels is higher than that of the rural-rural group. This suggests that urban-rural migrants may have additional sources of income, such as urban savings or investment returns. Consequently, their consumption in townships tends to be at a higher level-not only meeting basic living needs, but also including expenditures on housing improvement, children's education, and cultural or recreational activities.

Overall, for shrinking townships, both urban-rural and rural-rural mobile populations exhibit similar structural characteristics, but also reveal internal heterogeneity. This heterogeneity brings diverse development dynamics and demands, but may also lead to social conflicts and challenges, such as interest coordination among different groups and the differentiated provision of public services. Therefore, it is essential to propose targeted strategies based on these influencing factors.**(Figure 6)**

4.4 Influencing factors of floating population structure in shrinking towns

Based on the distribution, connectivity characteristics, and migrant population structure of shrinking townships in the Shanghai metropolitan area—and in light of current development conditions—the formation of their population structure is primarily influenced by a combination of economic development, geographic location, policy and institutional frameworks, and sociocultural factors.

Firstly, the impact of economic and industrial development: The Shanghai metropolitan area is dominated by the secondary and tertiary sectors, with agriculture playing a less prominent role. As a result, workers in agriculture-related industries tend to have relatively higher educational attainment. Among urban–rural migrants, there is a higher proportion of well-educated and skilled individuals who are more likely to migrate to cities or peri-urban townships to engage in jobs associated with the secondary and tertiary industries. The overall economic development level of the townships is relatively low, with unstable and slow-growing incomes, resulting in a predominantly low-income and low-consumption mobile population. Among urban-rural migrants, some individuals accumulate significant wealth through employment in cities, resulting in relatively higher income and consumption levels. In contrast, rural-rural migrants tend to have lower income and consumption levels overall.

Secondly, the influence of geography and spatial conditions: Shrinking towns are mostly located in the outer regions of the metropolitan area or in intercity border zones (such as Chongming in Shanghai and Rudong in Nantong), where the radiation effect of the central city is weak. In areas like Ningbo, Zhoushan, and Huzhou, geographical barriers such as the Siming and Tianmu Mountains limit external connectivity. Rural–rural mobility networks exhibit more cross-boundary connections due to geographic proximity, while urban–rural networks are more constrained by administrative boundaries. The convenience of transportation also influences the direction and frequency of population mobility—areas with better transportation tend to attract more inflows, whereas poorly connected regions see less movement. These spatial differences also lead to variations in the structure of the mobile population.

Thirdly, the role of policies and institutions: Shrinking towns generally maintain strong internal connections within their respective districts and counties, with administrative barriers exerting significant influence. However, cross-boundary connections are more apparent in rural–rural networks, indicating that township-level interactions are less constrained by administrative borders. Policy plays a crucial role in shaping population flows. The siphoning effect of central urban areas and associated policies can draw population toward cities or peri-urban townships. Under the hukou and land systems, rural–rural migrants are often limited by land transfer regulations, leading them to engage primarily in seasonal or temporary work. By contrast, urban–rural migrants benefit from urbanization policies, which often grant them more stable living conditions.

Lastly, sociocultural influences: Men, as the primary labor force and income earners in households, have higher mobility rates. In urban-rural migration, “family-based migration” is common, with couples working together or choosing jobs nearby, leading to a more balanced gender ratio. Women are more likely to migrate into townships through marriage and are typically employed in services or household-related work-a trend more prominent in rural–rural migration. Public services in town-s-particularly in education and healthcare-are relatively underdeveloped, which contributes to higher internal mobility among lower-educated populations. Conversely, individuals with higher education and specialized skills are more inclined to migrate to cities or peri-urban townships in search of better educational and healthcare resources.

In summary, the population structure of shrinking townships in the Shanghai metropolitan area is shaped by the combined effects of economic positioning, policy guidance, geographic conditions, and sociocultural factors. The internal heterogeneity of these townships calls for policies that can accurately identify the needs of different groups. Through industrial restructuring, optimization of public services, and institutional innovation, shrinking townships can be guided to shift from passive decline toward a model of “smart shrinkage.”

5. Conclusions

This study analyzes the characteristics of two types of mobile populations: urban-rural and rural-rural migrants, in shrinking townships within the Shanghai metropolitan area. It summarizes key structural features including gender, age, educational attainment, income, and consumption levels, and identifies their primary influencing factors. Based on the current development status of these shrinking townships, the following development recommendations are proposed:

First, to address regional development imbalances, the siphoning effect of central urban areas and industrial hollowing in peripheral townships should be mitigated through **"differentiated county-level economic positioning." For example, peripheral townships in Shanghai could focus on health and wellness services or cultural and tourism functions, while Suzhou, Wuxi, and Changzhou could strengthen support for manufacturing industries.

Second, to resolve disparities in public service provision, mechanisms for the sharing of education and healthcare resources within counties should be improved to serve rural-rural migrants, while urbanization-related support services should be enhanced for urban-rural migrants.

Third, to address mismatches between skills and industrial needs, a "dual-track training system combining education and vocational skills" should be established to align with the demands of industrial upgrading in townships.

Lastly, population management should be stratified: entrepreneurial support should be provided to highly skilled urban–rural migrants, while employment security and the formalization of informal economies should be strengthened for low-skilled rural-rural migrants.

By employing a population mobility network analysis approach, this study explores the characteristics and patterns of migrant populations in shrinking areas from spatial, mobility, and structural perspectives. The findings provide valuable insights for local governments to formulate targeted population policies, optimize resource allocation, and enhance regional development potential.

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